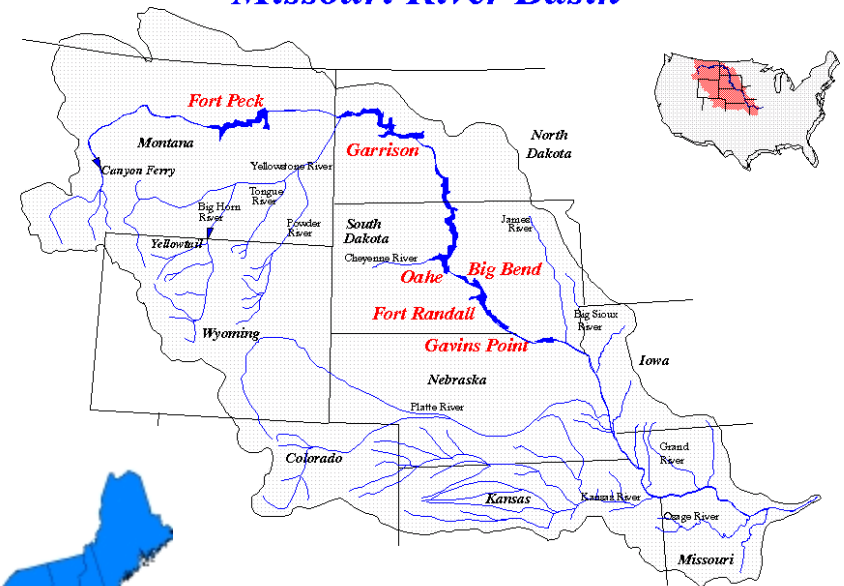


The 2010-2011 Missouri River Flood:

*An experimental rapid assessment
of weather and climate conditions
leading to high flows*



Missouri River Basin

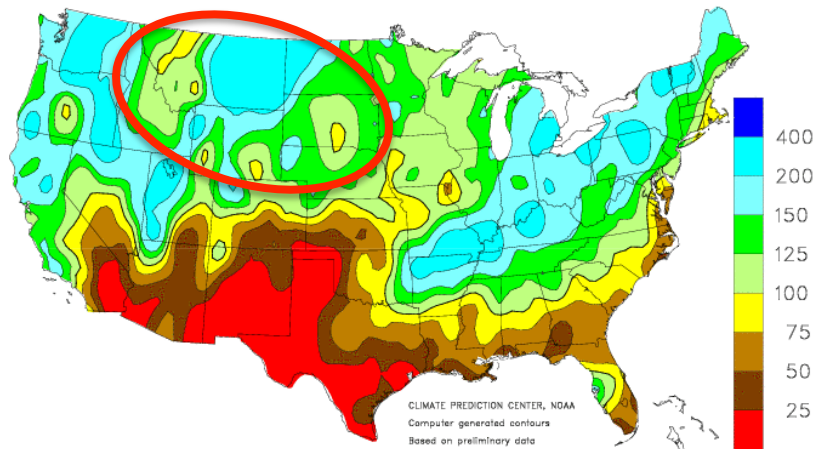


Robert Webb	Doug Kluck
David Easterling	Arun Kumar
Martin Hoerling	Jon Eischeid
David Anderson	Russel Vose
Scott Applequist	Tom Gurr
Gregg Schalk	Juliann Meyer
Chunzai Wang	

Tom Perkins and the NRCS Snow
Survey and Water Supply
Forecasting Staff

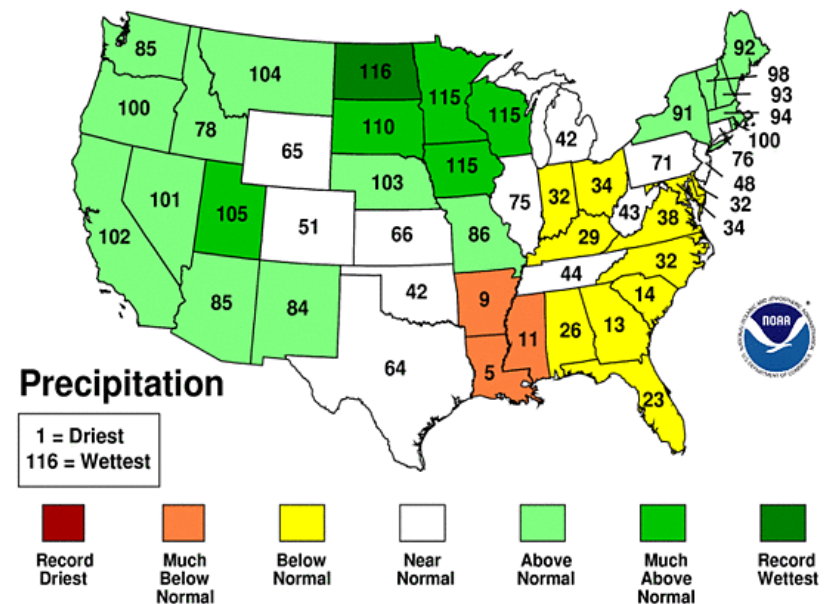
Missouri River Basin Precipitation

March-April-May 2011 Observed Seasonal Mean Precipitation (% of Normal)

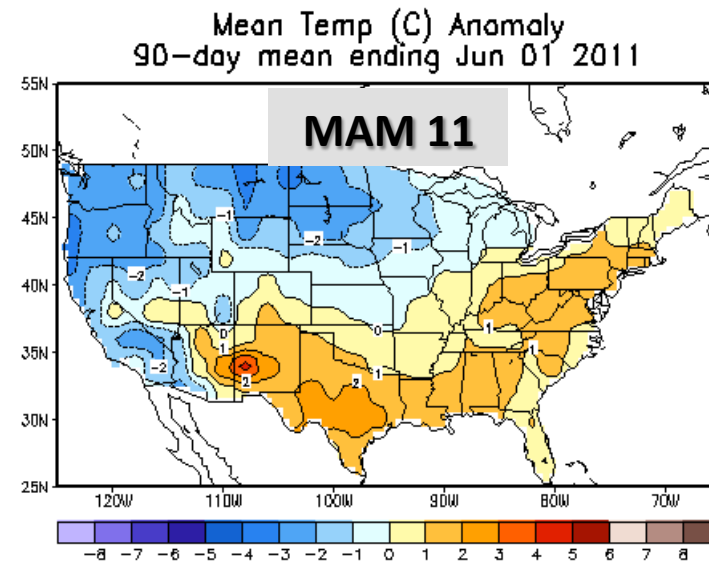
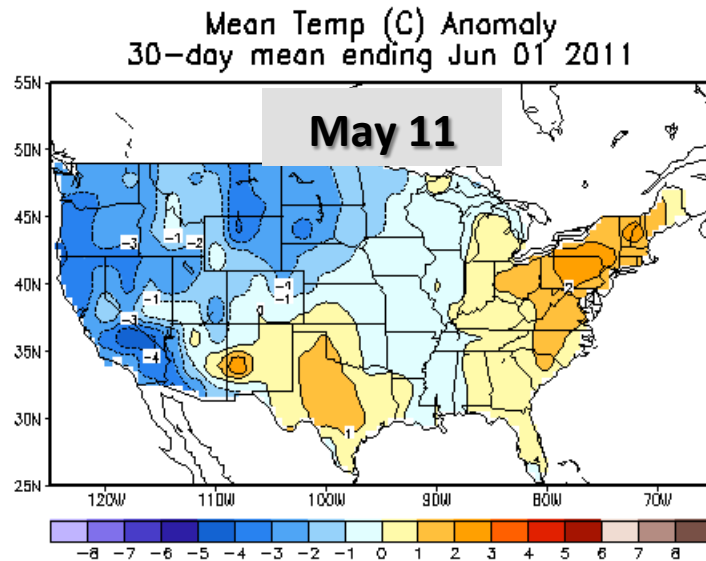
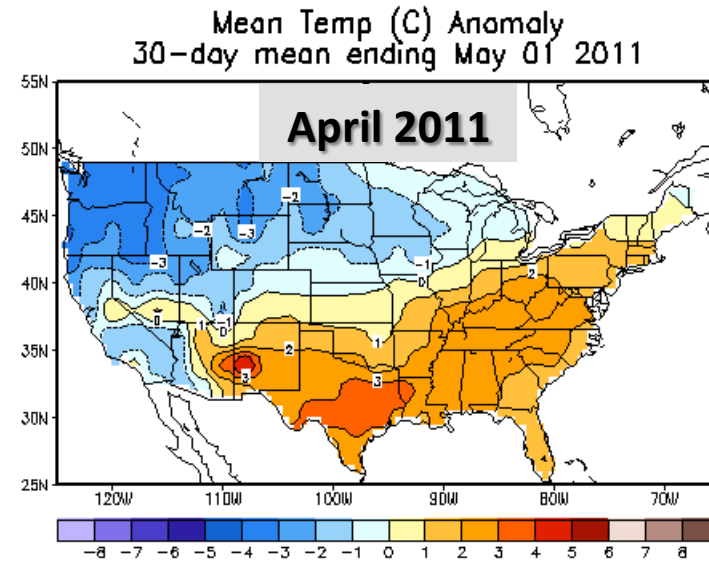
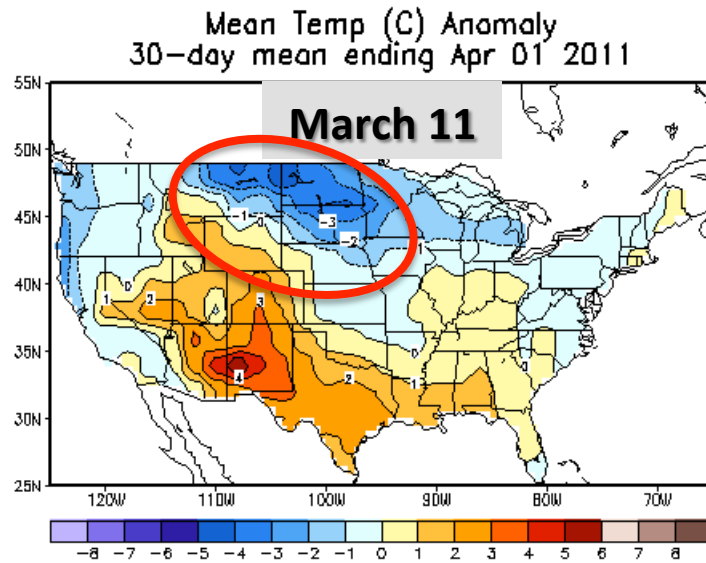


January-December 2010 Statewide Ranks

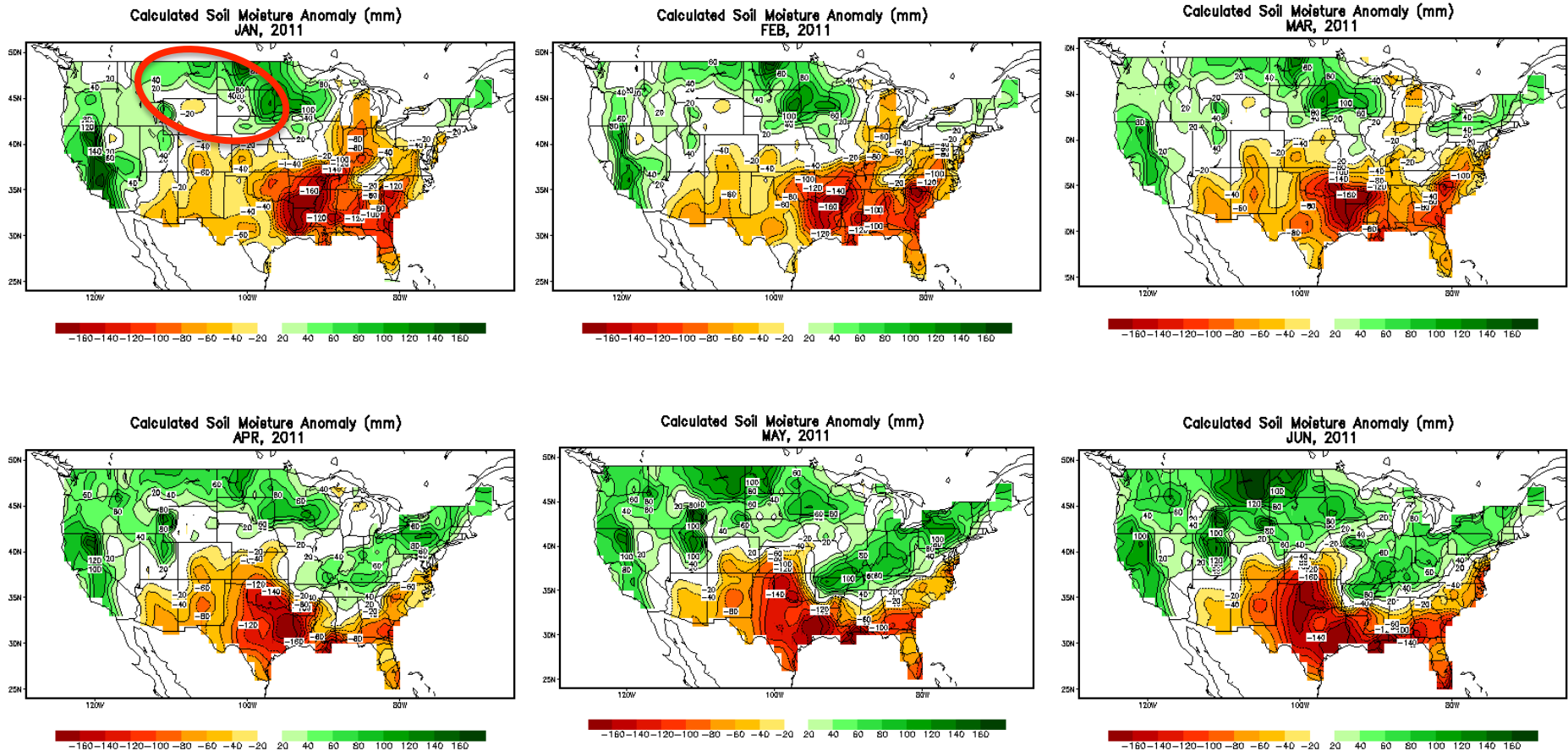
National Climatic Data Center/NESDIS/NOAA



January – June 2011 Observed Temperature (departure from normal) - °C



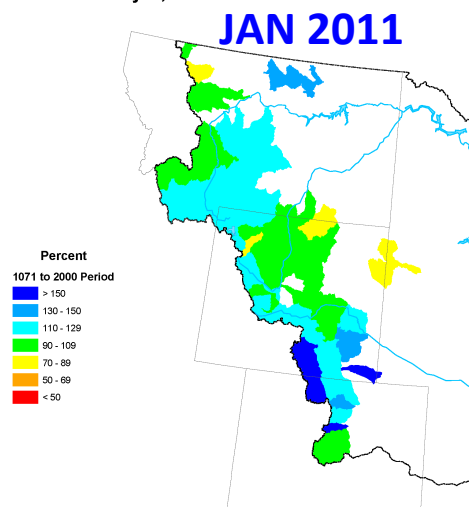
NOAA Soil Moisture Anomaly Analysis



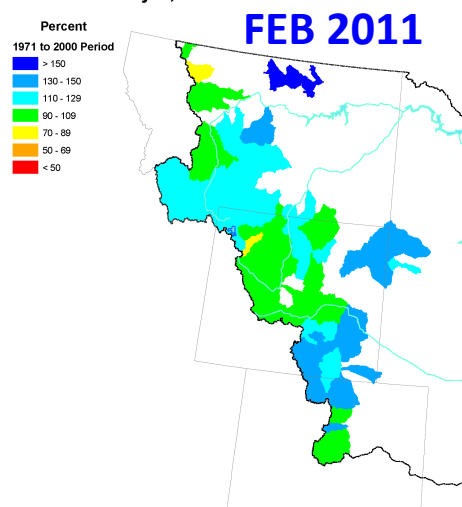
NRCS Snowpack Maps for the Missouri River Basin

Prepared by USDA Natural Resources Conservation Service, National Water and Climate Center, Portland, Oregon

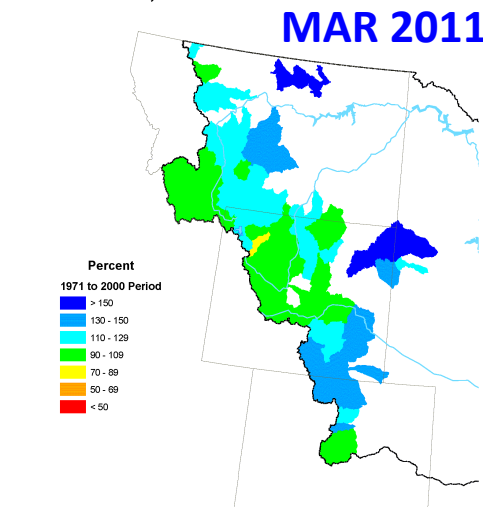
Missouri River Basin Mountain Snowpack
as of January 1, 2011



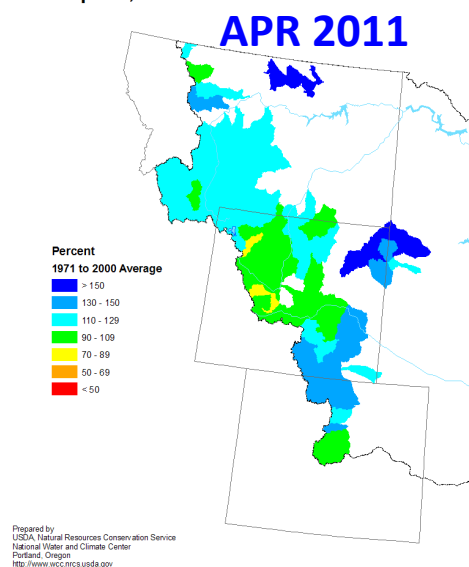
Missouri River Basin Mountain Snowpack
as of February 1, 2011



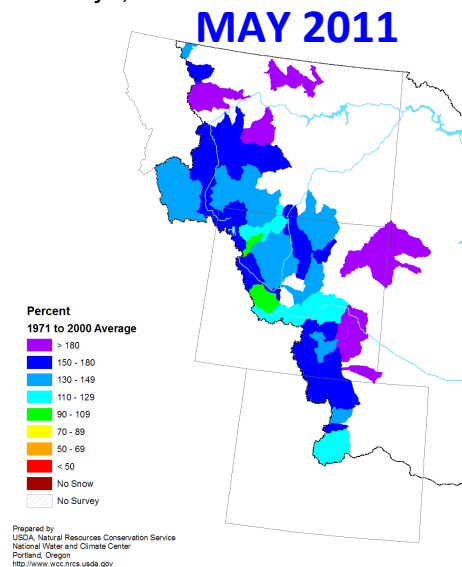
Missouri River Basin Mountain Snowpack
as of March 1, 2011



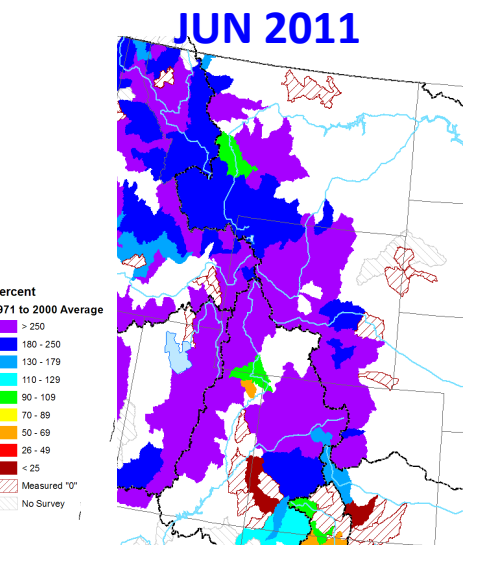
Missouri River Basin Mountain Snowpack
as of April 1, 2011



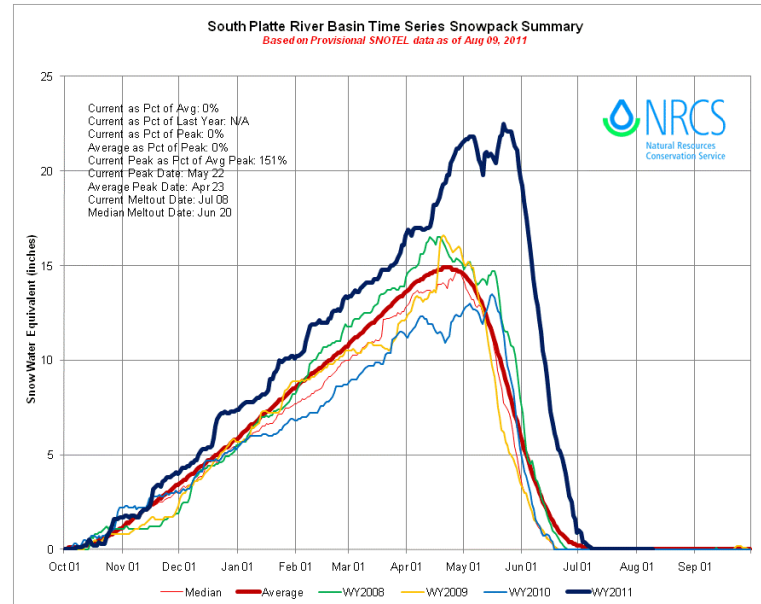
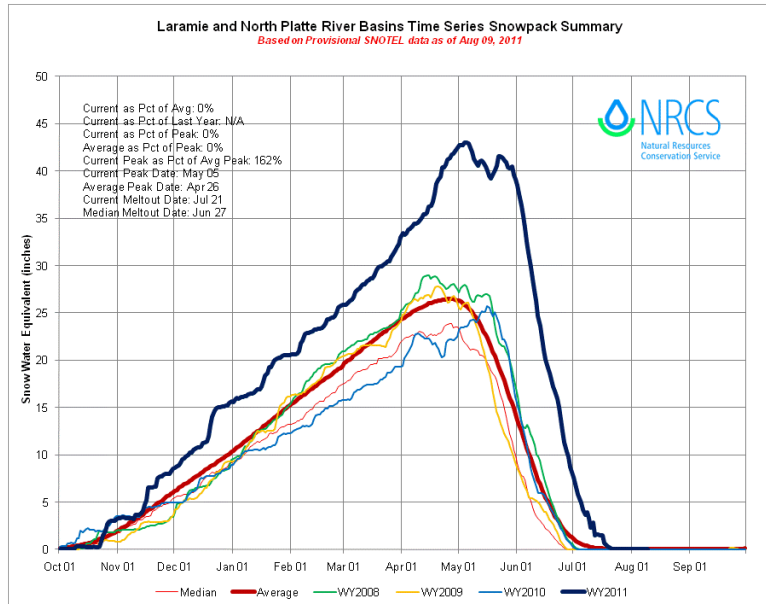
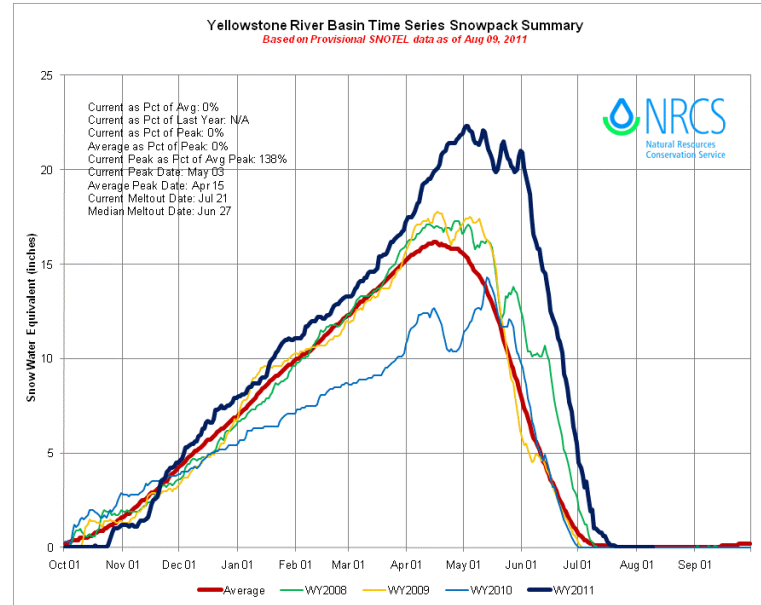
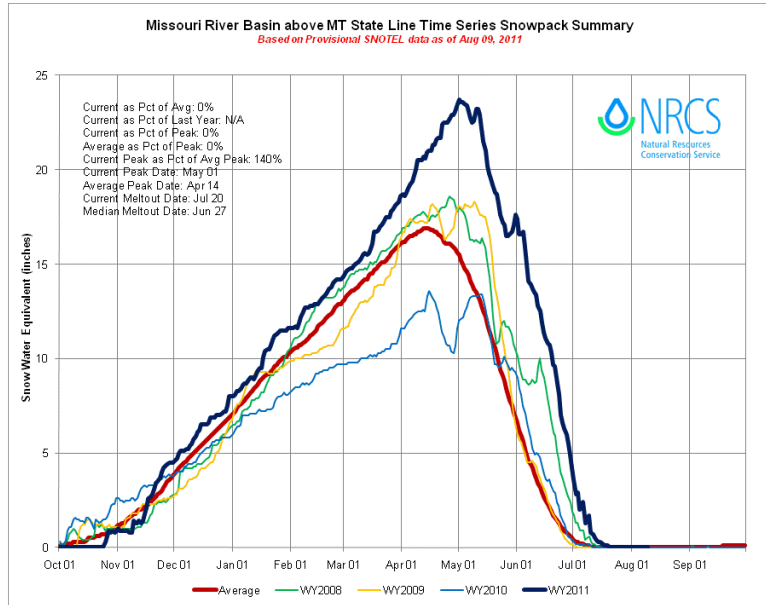
Missouri River Basin Mountain Snowpack
as of May 1, 2011



Missouri River Basin Mountain Snowpack
as of June 1, 2011

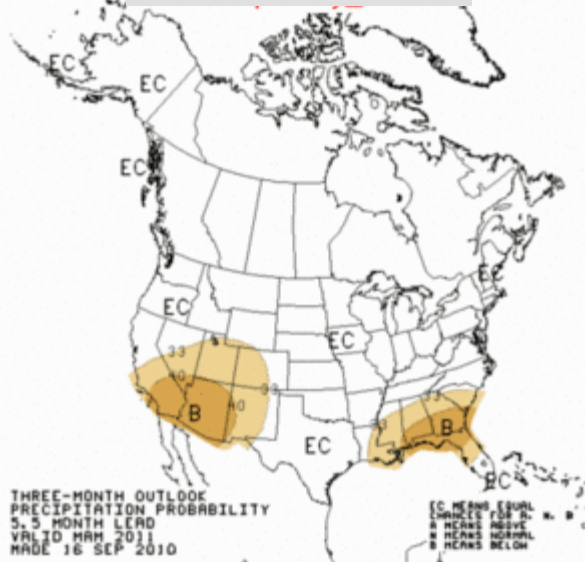


Missouri River Basin Snowpack Evolution

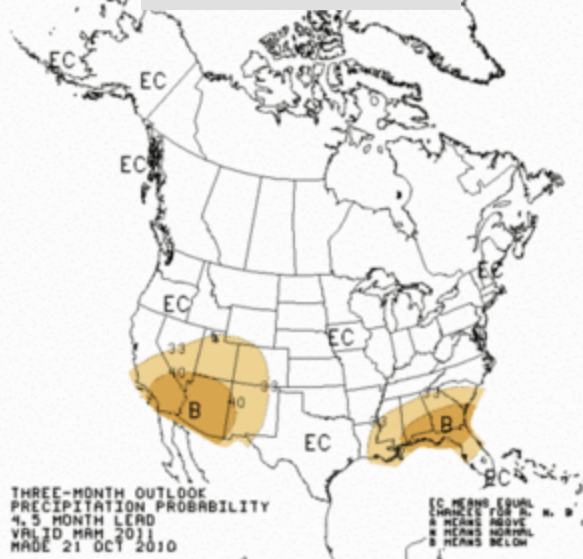


***Wet Spring
Caused Late
Increase in
Upper Basin
Snowpack.
Cold Spring
Extended
Snowpack
Peaks to the
end of May.***

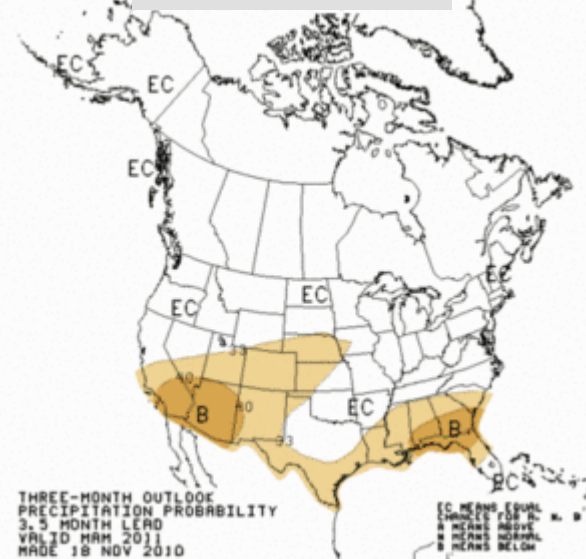
September 10



October 10

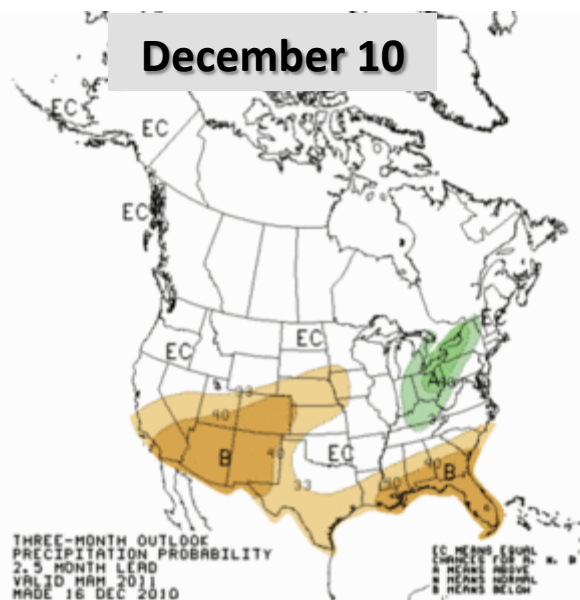


November 10

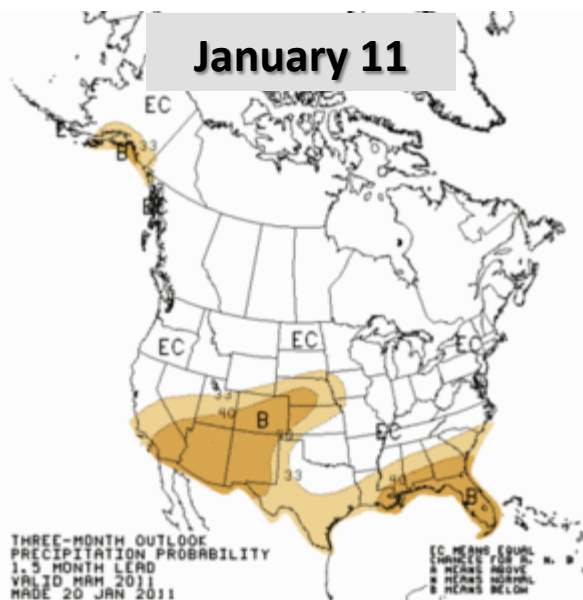


NOAA CPC Precipitation Forecast for MAM 2011

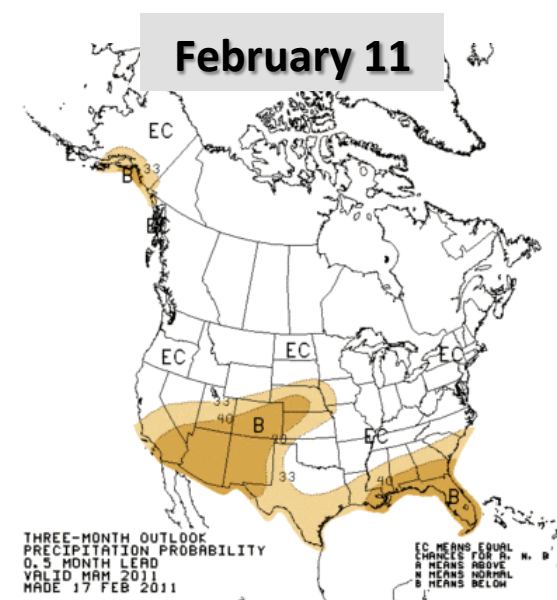
December 10



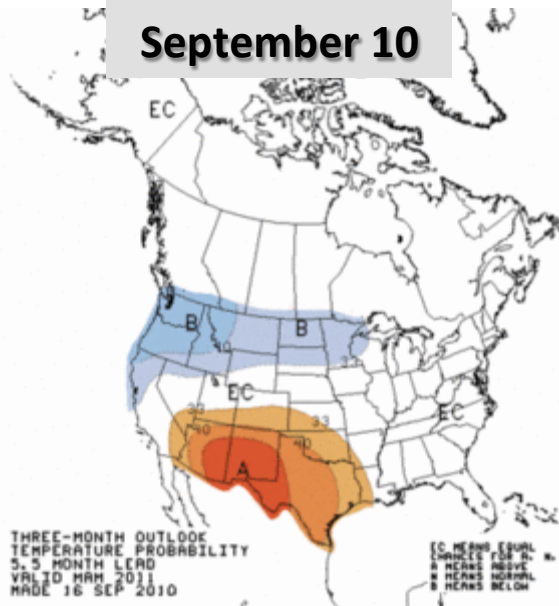
January 11



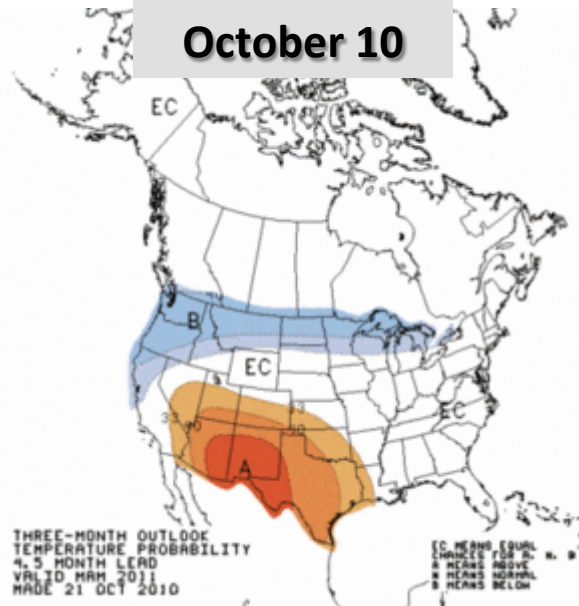
February 11



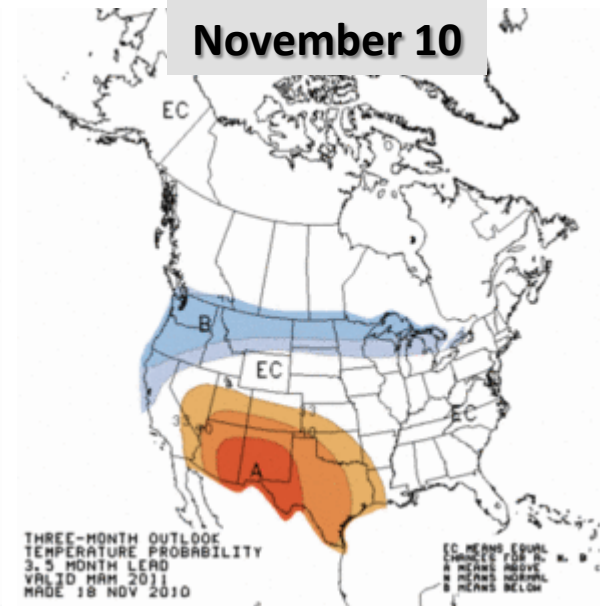
September 10



October 10

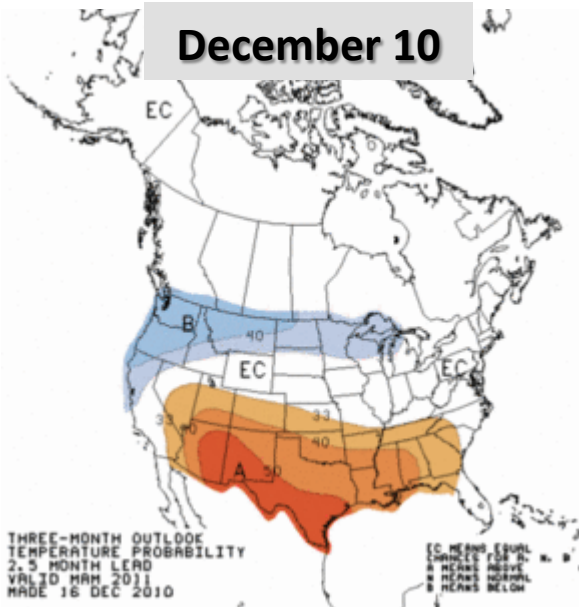


November 10

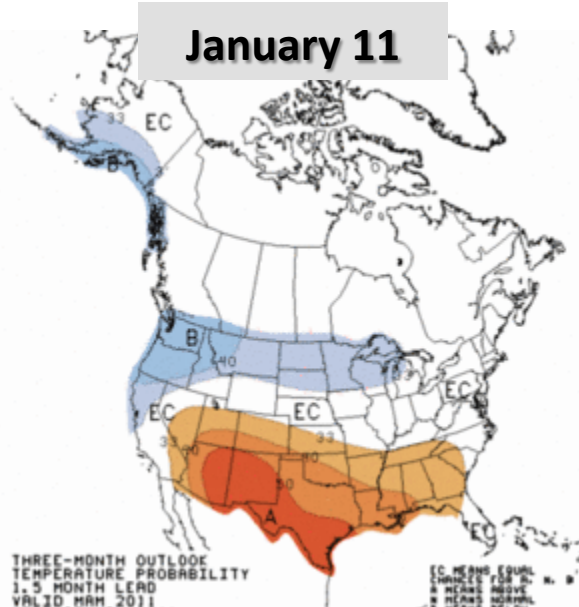


NOAA CPC Temperature Forecast for MAM 2011

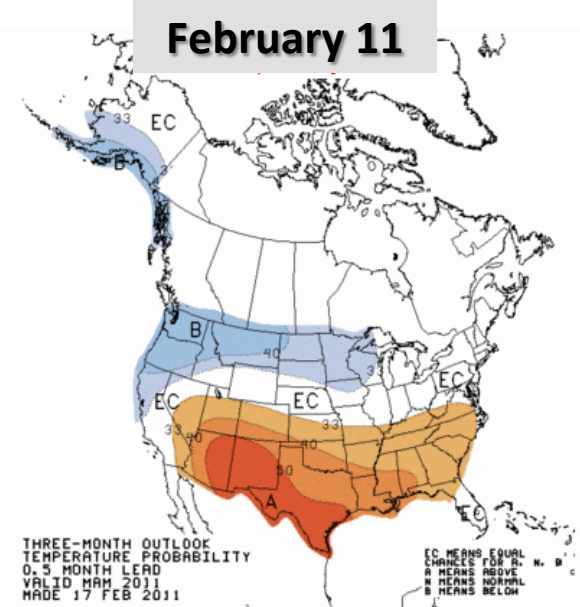
December 10



January 11



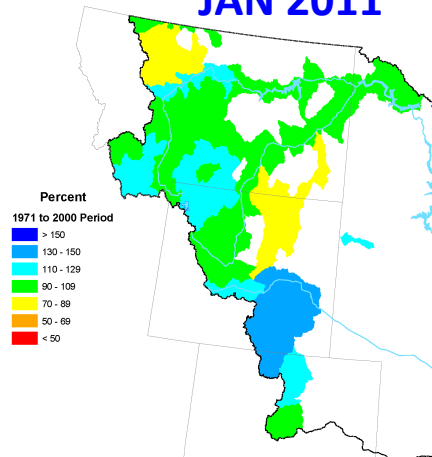
February 11



NRCS Spring & Summer Streamflow Forecast Maps for the Missouri River Basin

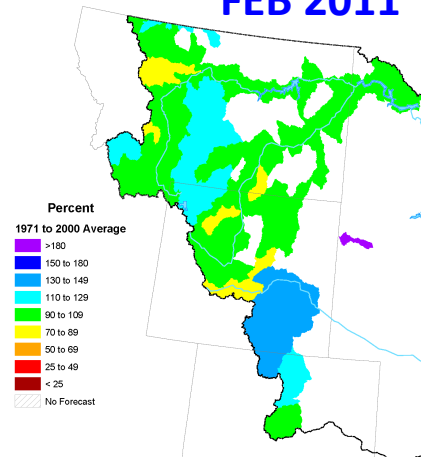
Missouri River Basin
Spring and Summer Streamflow Forecasts
as of January 1, 2011

JAN 2011



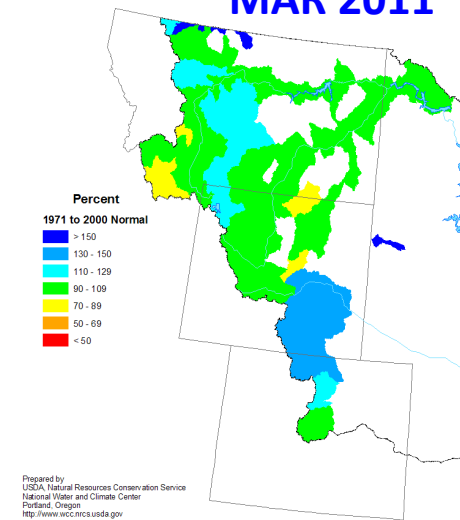
Missouri River Basin
Spring and Summer Streamflow Forecasts
as of February 1, 2011

FEB 2011



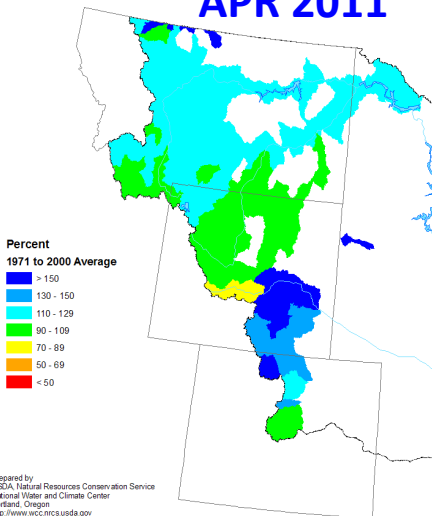
Missouri River Basin
Spring and Summer Streamflow Forecasts
as of March 1, 2011

MAR 2011



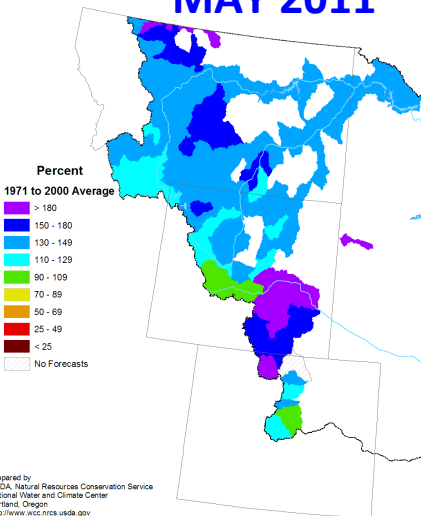
Missouri River Basin
Spring and Summer Streamflow Forecasts
as of April 1, 2011

APR 2011

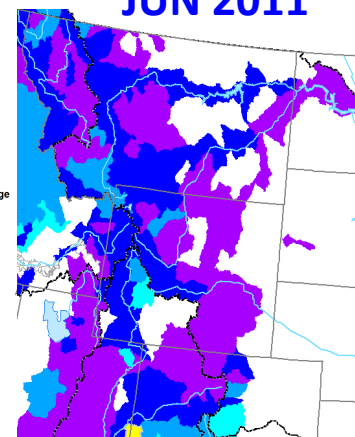


Missouri River Basin
Spring and Summer Streamflow Forecasts
as of May 1, 2011

MAY 2011

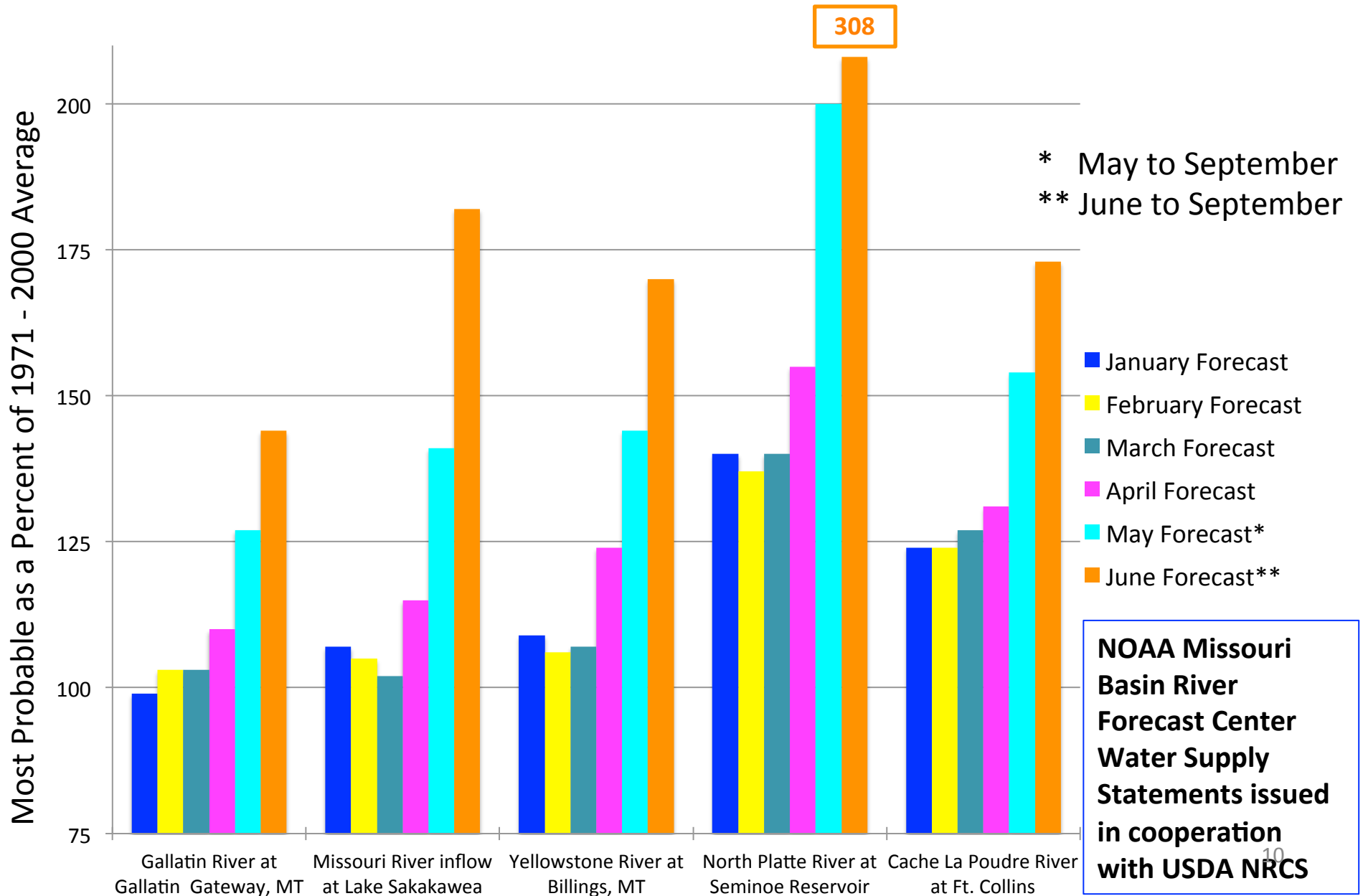


JUN 2011



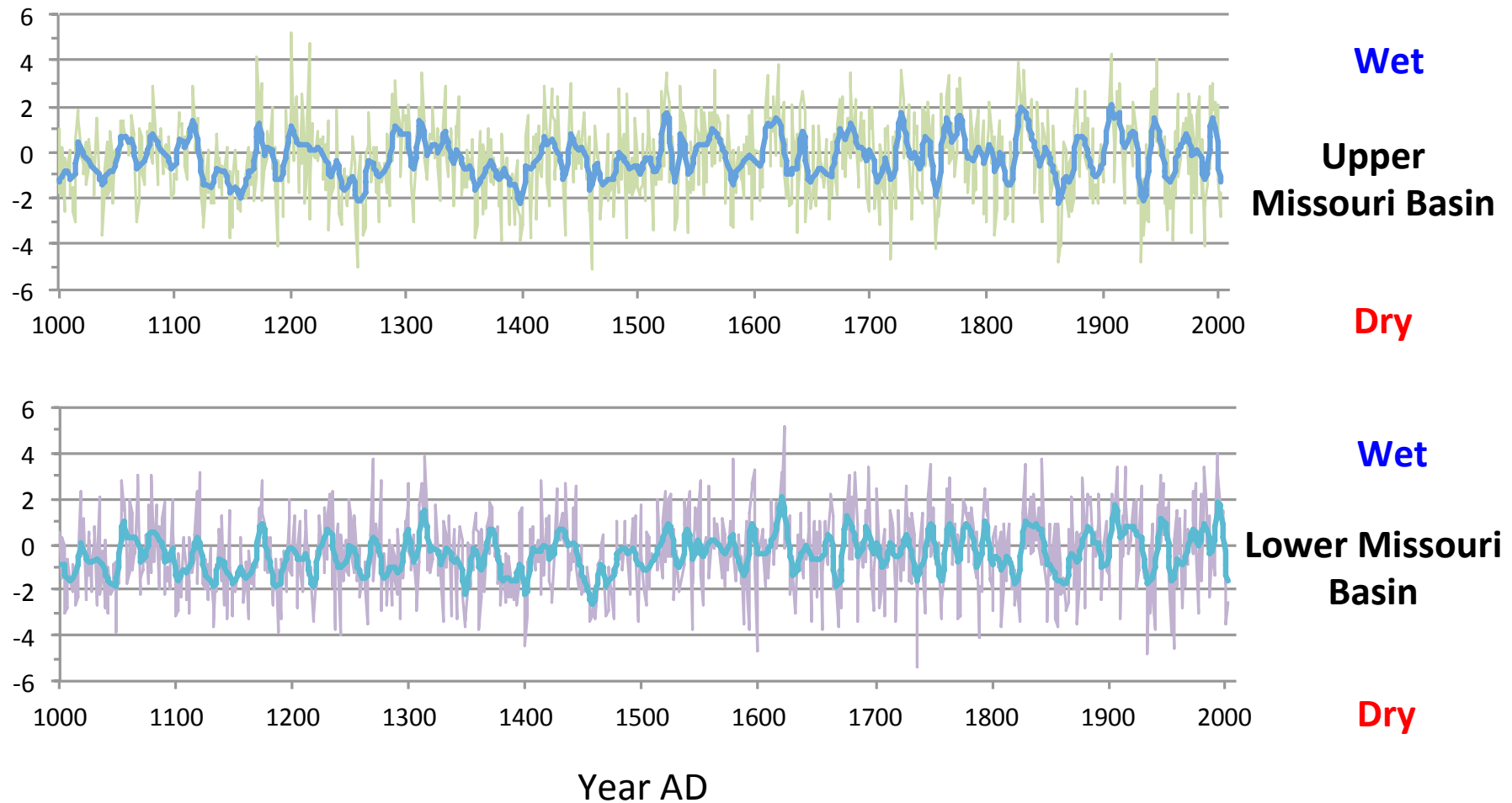
Prepared by USDA Natural Resources Conservation Service, National Water and Climate Center, Portland, Oregon

April to September 2011 Most Probable Streamflow for select Missouri River Forecast Points



Paleoclimate Perspective

Tree ring reconstructions of Palmer Drought Severity Index (PDSI)



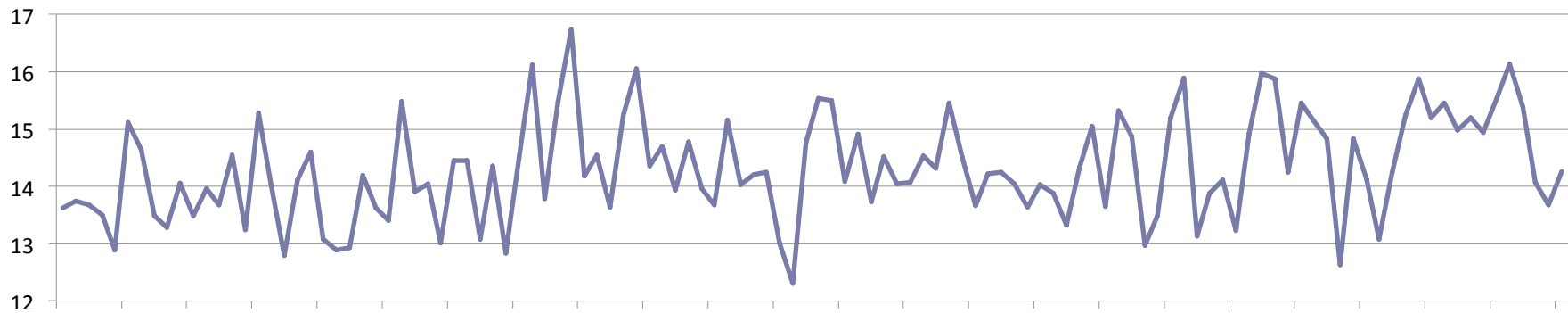
Interannual and decadal climate variability resulting in shifts between wet and dry conditions common over the last 1000 years

Cook, E.R., et al. (2008)

Data from NOAA National Climatic Data Center

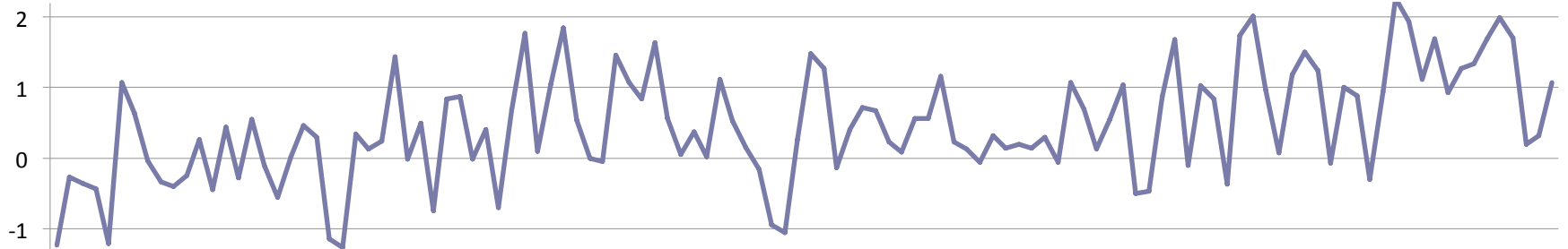
Missouri River Basin: Long term Climate Trends (Jan-Dec)

Tmax (°C)

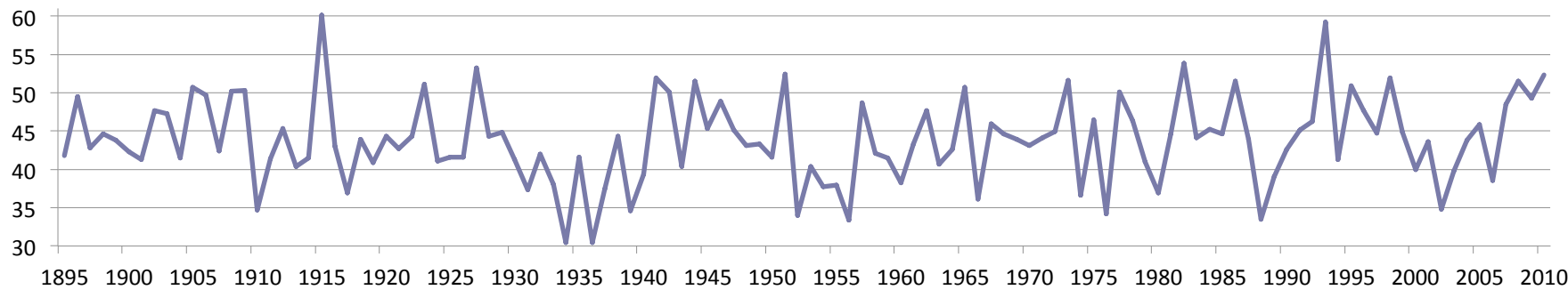


Tmin (°C)

warming trends



Precipitation (mm)

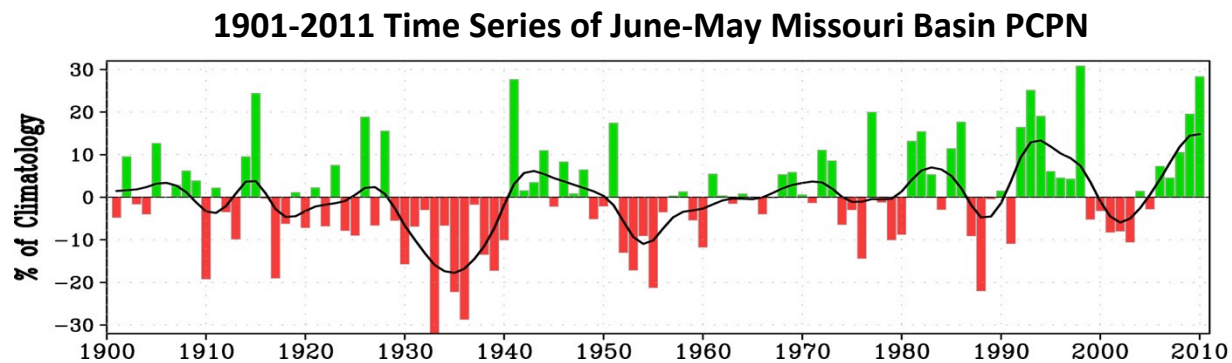
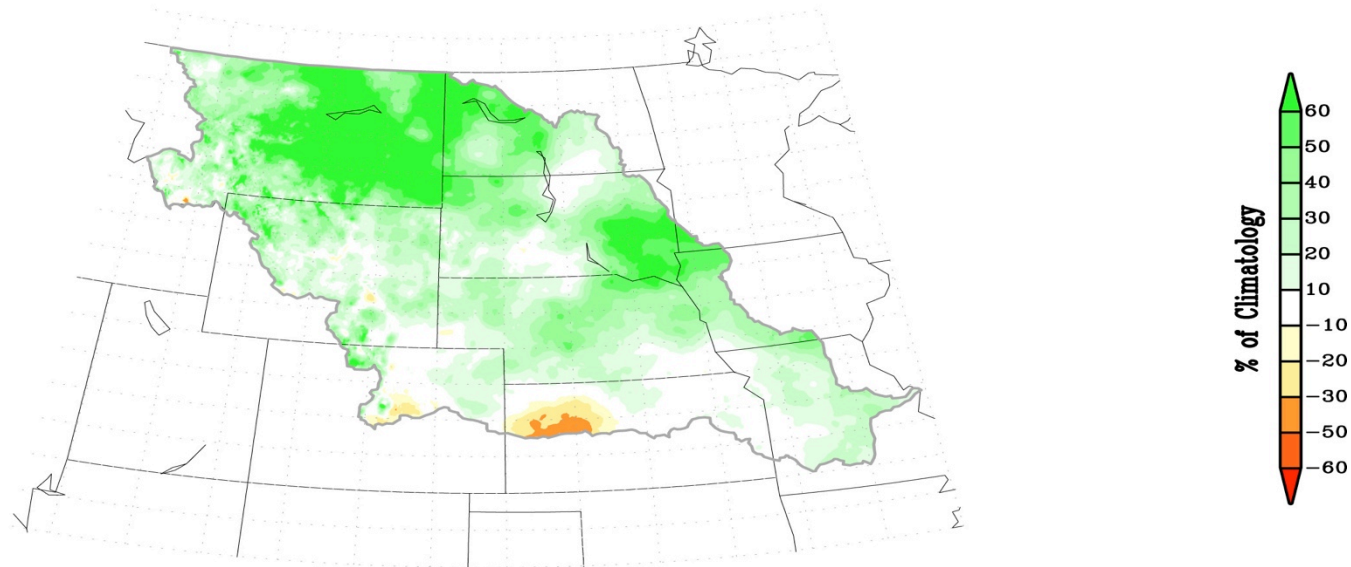


Year AD

NOAA National Climatic Data Center

Missouri River Drainage Basin 12-month Precipitation Departures: June 2010 – May 2011

% of Climatology; Data Source PRISM

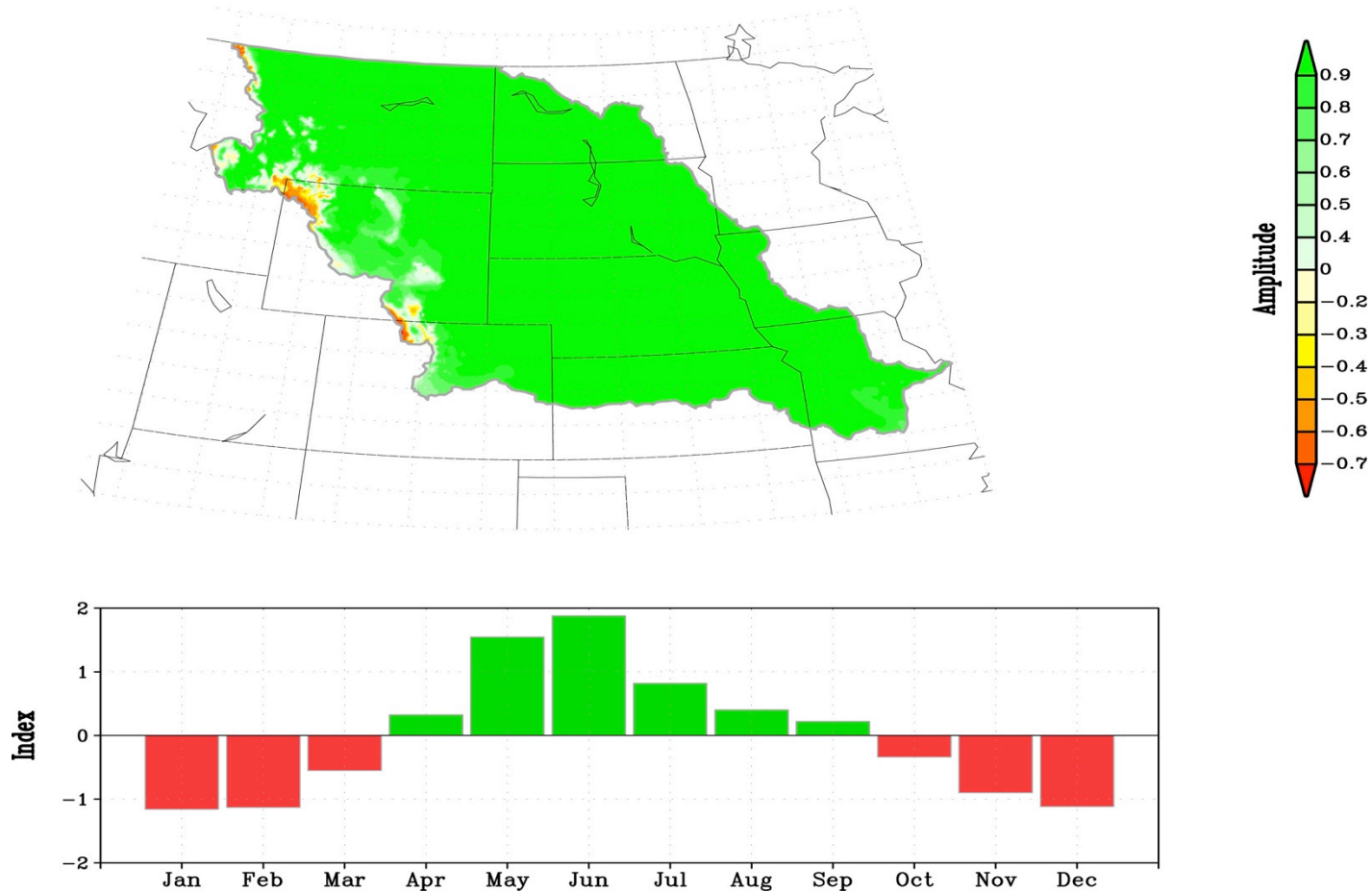


2010/11 Ranks Among the Top 3 Wettest Years for the Missouri Basin

Seasonality of Precipitation

Spring is the Missouri Basin's Rainy Season

Principal Pattern of Climatological Precipitation

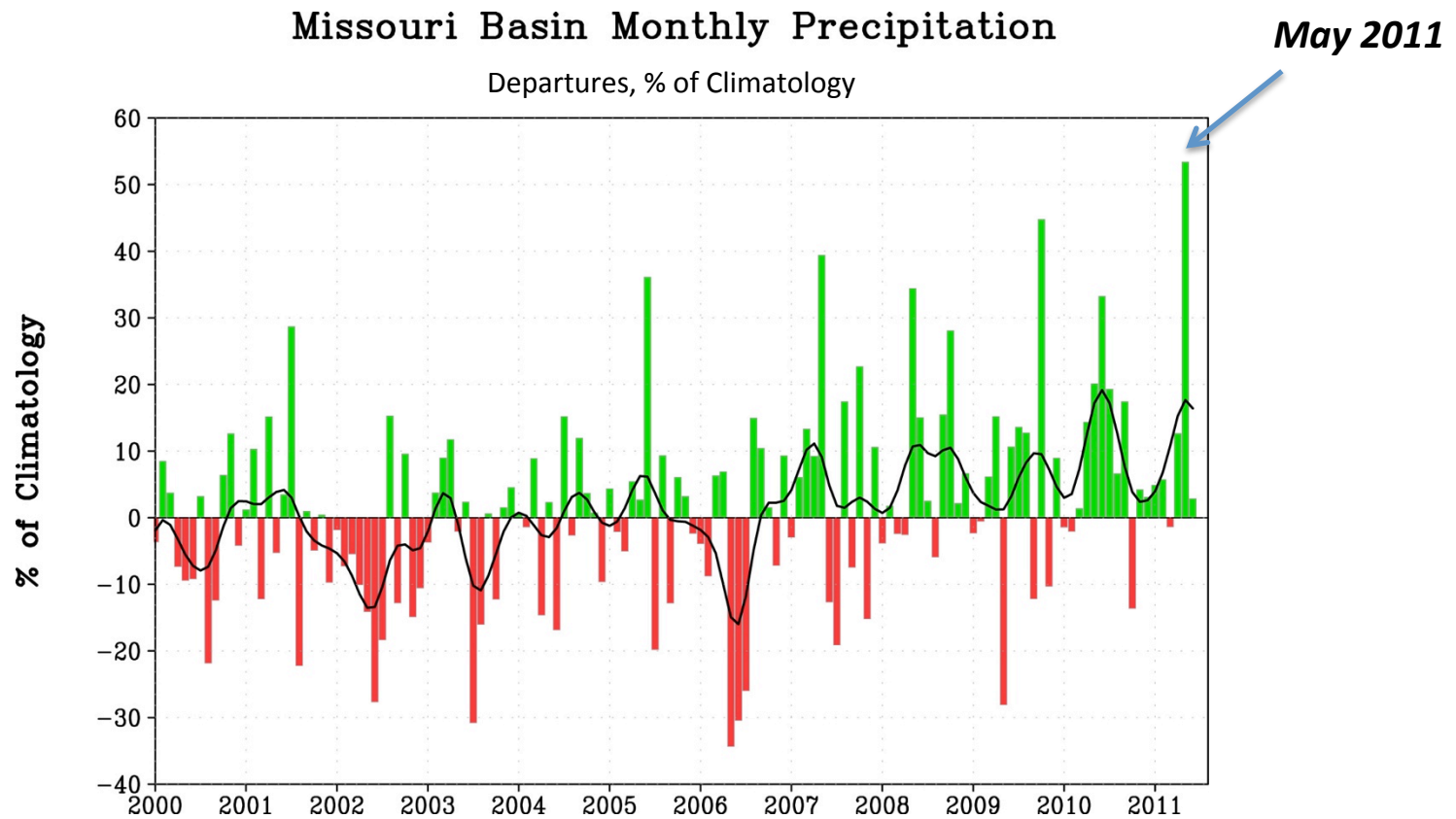


But, severe Missouri River floods often stem from the combination of a prolonged wet period, rapid snowmelt, and heavy spring rains.

Spring 2011 Was *Very Wet* : May 2011 Second Wettest since 1901

° *Caused a Late Surge in Upper Basin Mtn Snowpack*

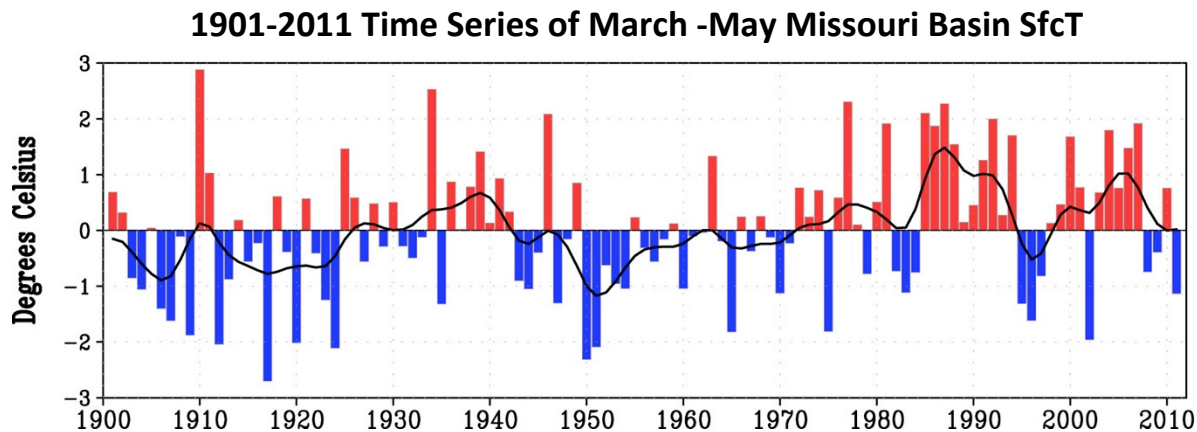
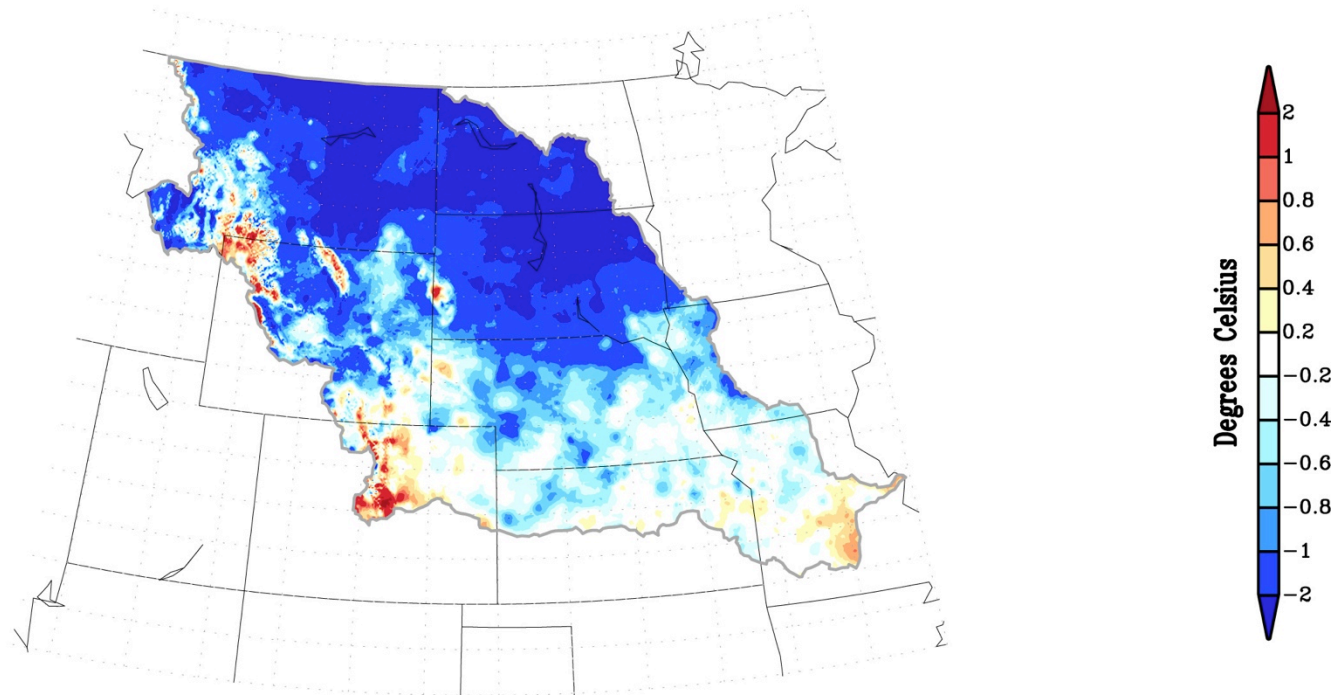
°



Spring Was *Unusually Cold* : Contrary to a Recent Warming Trend

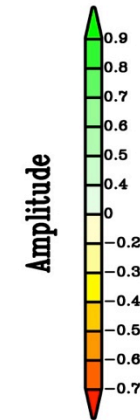
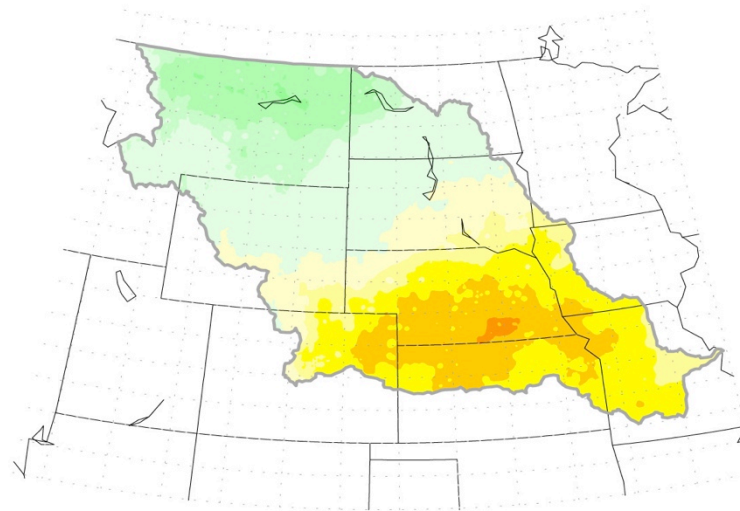
° *The Cold Spring Extended Snowpack Peak into May*

Missouri River Basin March–May Tmp, 2011

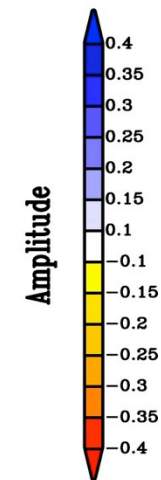
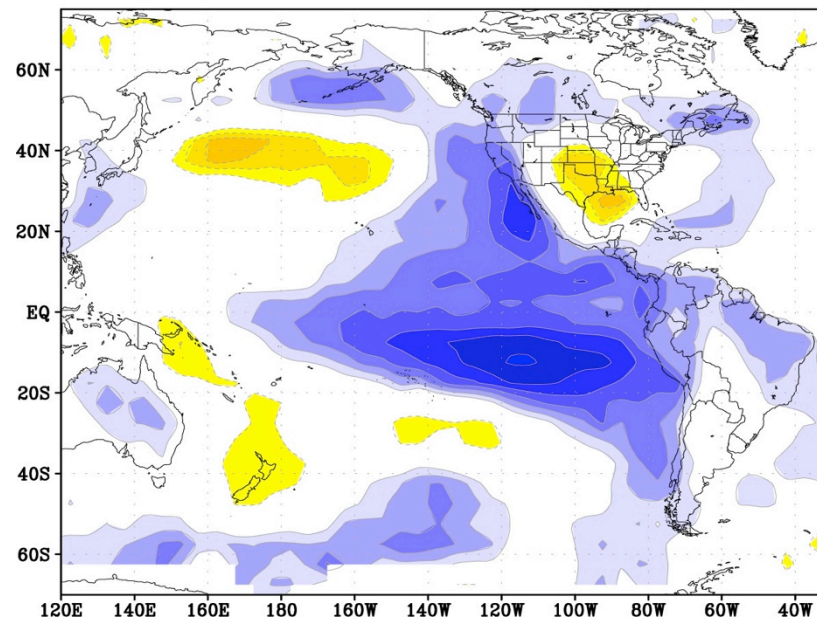


La Nina Has A Strong Impact on Missouri Basin Annual Climate

La Nina Impact on Annual Missouri Basin PPT
1901-2010



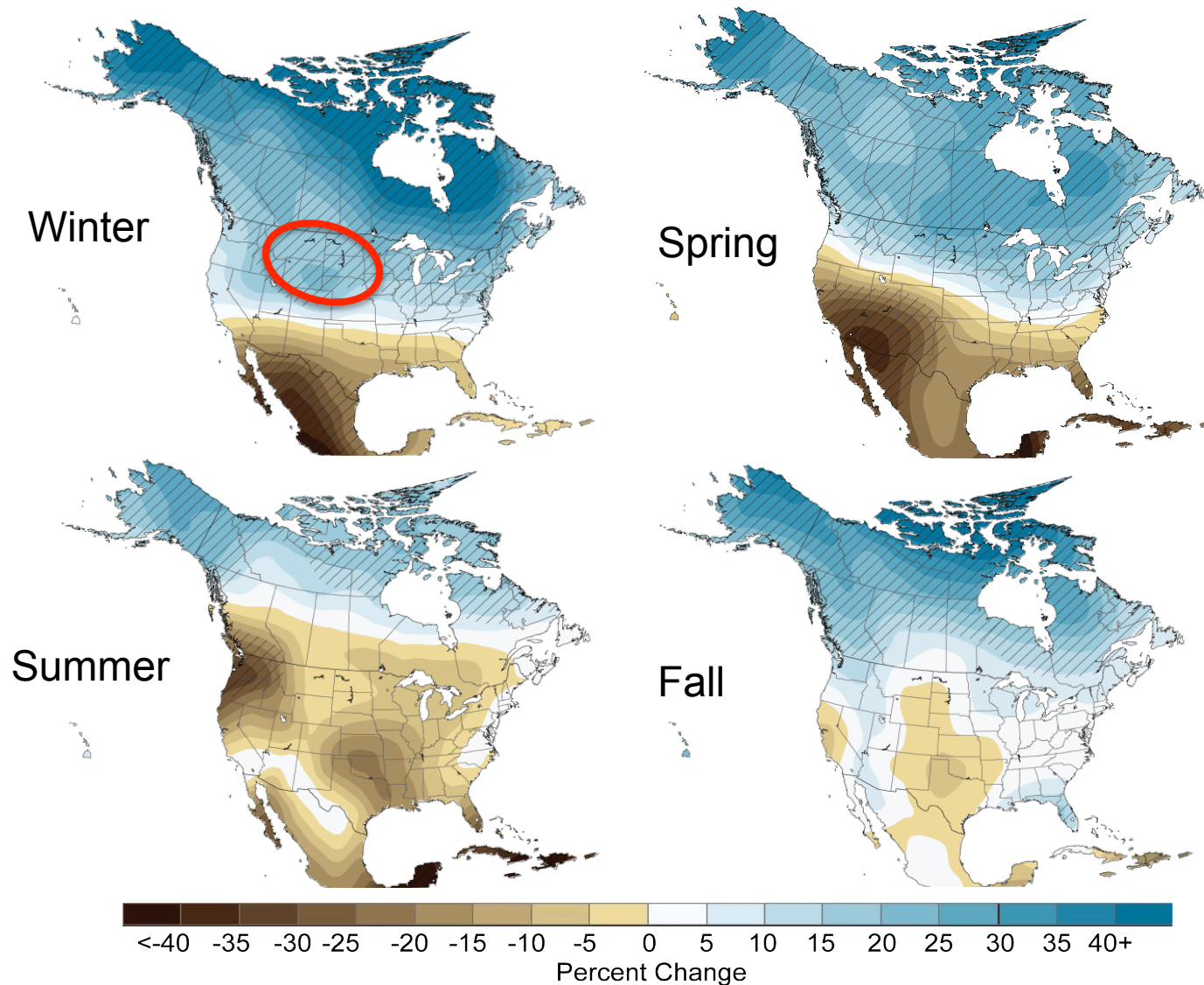
Precipitation



Temperature

Projected Future Climate Change Impact on North American Precipitation 2080-2099

Ensemble mean from 15 climate models for high emission scenario (A2)



Global Climate Change Impacts in the United States. Karl, Melillo, and Peterson, (eds.), 2009.

NOAA El Niño/Southern Oscillation (ENSO) Diagnostic Discussion

EL NIÑO/SOUTHERN OSCILLATION (ENSO) DIAGNOSTIC DISCUSSION

issued by
CLIMATE PREDICTION CENTER/NCEP
4 August 2011

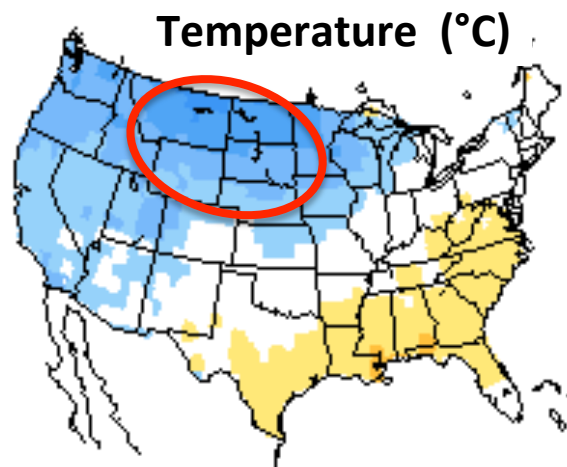
ENSO Alert System Status: La Niña Watch*

**Watch: Issued when conditions are favorable for the development of La Niña conditions within the next six months.*

- ENSO-neutral conditions are present across the equatorial Pacific.
- Sea surface temperatures (SST) are near-average across the equatorial Pacific Ocean.
- Atmospheric circulation anomalies still reflect aspects of La Niña.
- ENSO-neutral is expected to continue into the Northern Hemisphere fall 2011, with ENSO-neutral or La Niña equally likely thereafter.

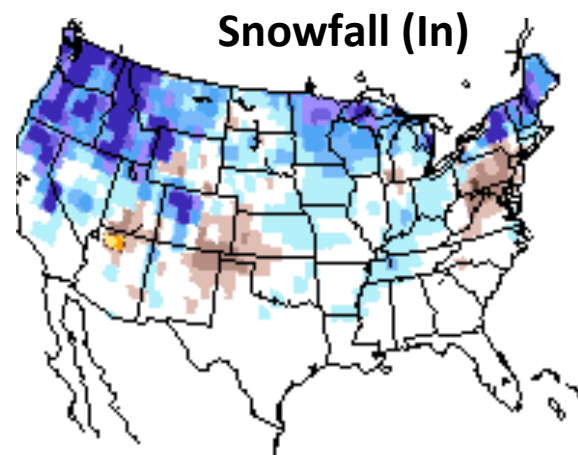
Summary From Weekly update prepared by Climate Prediction Center/NCEP 8 August 2011

La Niña Winter Impacts

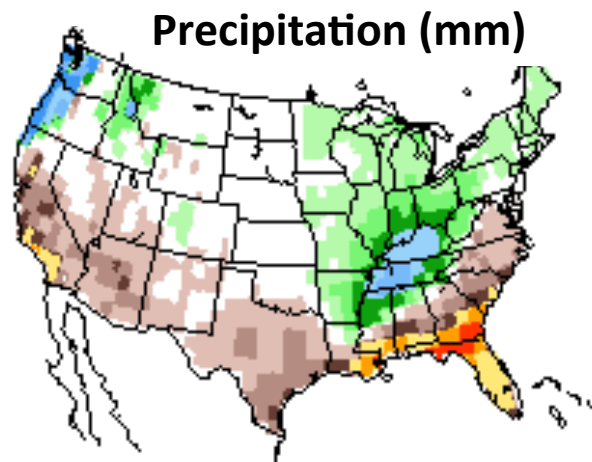
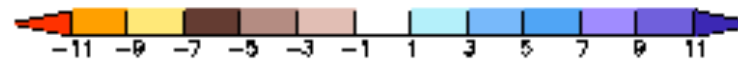
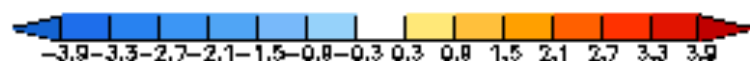


Temperature (°C)

Mean composite anomalies for January/February/March relative to the 1981-2010 average.



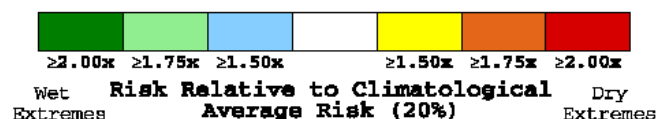
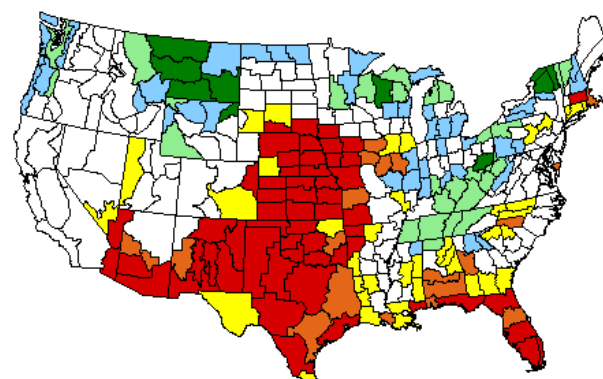
Snowfall (In)



Precipitation (mm)



JFM Precipitation Extremes During La Nina
Risk of Extreme Wet or Dry Years



NOAA ESRL Physical Sciences Division

Take Away Points

For the Missouri River Drainage Basin :

- ° **June 2010-May 2011 Ranked Among the Top 3 Wettest 12-month Periods Since 1901.**
Yet, the other 2 wettest June-May periods (1941/42 & 1998/99) did not have severe, basin wide flooding
- ° **A Monthly Sequence of Almost Unbroken Wet Months Began in early 2010.**
High soil moisture content conducive to immediate runoff to streams.
- ° **Spring (March-May) 2011 was Unusually Cold**
Western basin snowpack melt was deferred at least 1 month, until May 2011.
- ° **May is a Climatological Wet Month---May 2011 was the 2nd Wettest on Record Since 1901.**
Heavy May rains commingled with high May snowpack, and antecedent saturated soils to induce severe flooding
- ° **Since 1901, La Nina Has Impacted Missouri Basin Precipitation and Temperature.**
The 2010-11 La Nina event was very likely an important contributing factor to the flooding event.